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Ministry of Energy, Mines and
Petroleum Resources
Hon. Anne Edwards, Minister

MINERAL RESOURCES DIVISION
Geological Survey Branch

**GEOLOGY AND MAJOR ELEMENT
GEOCHEMISTRY OF THE MOUNT
BRUSILOF MAGNESITE AREA,
SOUTHEASTERN BRITISH COLUMBIA
(82J/ 12, 13)**

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INTRODUCTION

KEYWORDS: Economic geology, industrial minerals, magnesite, Cathedral Formation, Middle Cambrian, chemical analyses.

A number of magnesite deposits, hosted either by ultramafic or sedimentary rocks, are known in British Columbia (Grant, 1987). The most important of these is the Mount Brussilof orebody hosted by dolomites of the Middle Cambrian Cathedral Formation.

The Mount Brussilof deposit was discovered by the Geological Survey of Canada during regional mapping (Leech, 1965). Baykal Minerals Ltd. and Brussilof Resources Ltd. staked and explored the deposit. In 1971, the two companies merged to form Baymag Mines Co. Ltd. Refratechnik GmbH. acquired Baymag Mines in 1979 (MacLean, 1988). In 1980, proven and probable geological reserves were 9.5 million tonnes grading over 95 per cent magnesia in the calcined product and 13.6 million tonnes of 93 to 95 percent magnesia in calcined product. Possible reserves were estimated at 17.6 million tonnes averaging 92.44 per cent magnesia in calcined product (Schultes, 1986). Previous investigations, including geological mapping, are described in detail by MacLean (1988). The geological descriptions in this paper are based on the field investigations by Simandl and Hancock (1991). This report compliments the earlier publication

by providing a large-scale geological map of the Mount Brussilof area and major oxide analyses of the magnesite-bearing rocks and other carbonate rocks of the Cathedral, Eldon and Pika formations. Its primary objective is the quick release of the geological map and raw geochemical information. Detailed interpretation of major and trace element geochemistry, including rare earths, will be released in a final report.

LOCATION

The Mount Brussilof deposit is located in southeastern British Columbia, approximately 35 kilometres north-east of Radium Hot Springs. It is accessible from Highway 93 by an all-weather unpaved road (Figure 1).

TECTONIC SETTING

The Mount Brussilof deposit is hosted by rocks of the Foreland tectonostratigraphic belt and is within the "Kicking Horse Rim", as defined by Aitken (1971, 1989). It lies east of a Cambrian bathymetric feature commonly referred to as the Cathedral escarpment (Fritz, 1990; Aitken and McIlreath, 1984, 1990). Leech (1966) described the same feature in the Mount Brussilof mine area (Figure 2, *in pocket*) as a "faulted facies change". In any event, the carbonate rocks east of this feature, which host the magnesite mineralization, were deposited in a shallower marine environment than their stratigraphic equivalents to the west.

STRATIGRAPHY AND LITHOLOGY

The stratigraphic relationship between rocks east of the Cathedral escarpment, and their deeper water equivalents to the west, commonly referred to as the Chancellor Formation, is described by Aitken and McIlreath (1984) and Stewart (1989).

All known occurrences of sparry carbonate, other than veins of calcite or dolomite a few centimetres thick, are located east of the Cathedral paleo-escarpment (Figure 2). A composite stratigraphic section of this area is shown in Figure 3. Stratigraphic thicknesses of the formations are approximate. The formations are described below in order from oldest to youngest.

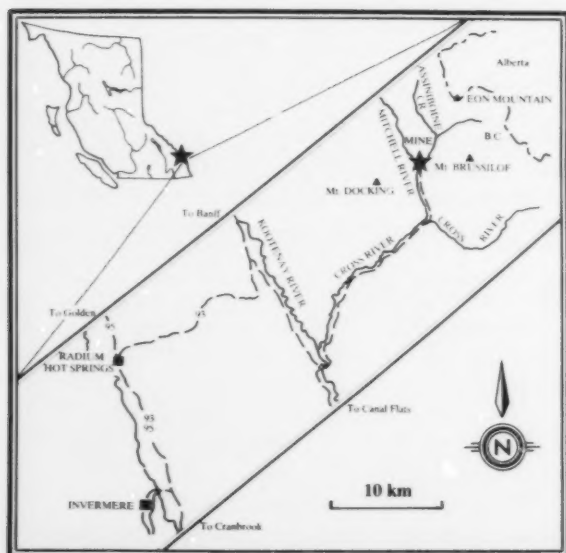


Figure 1. Location of the Mount Brussilof magnesite mine. (Simandl and Hancock, 1991).

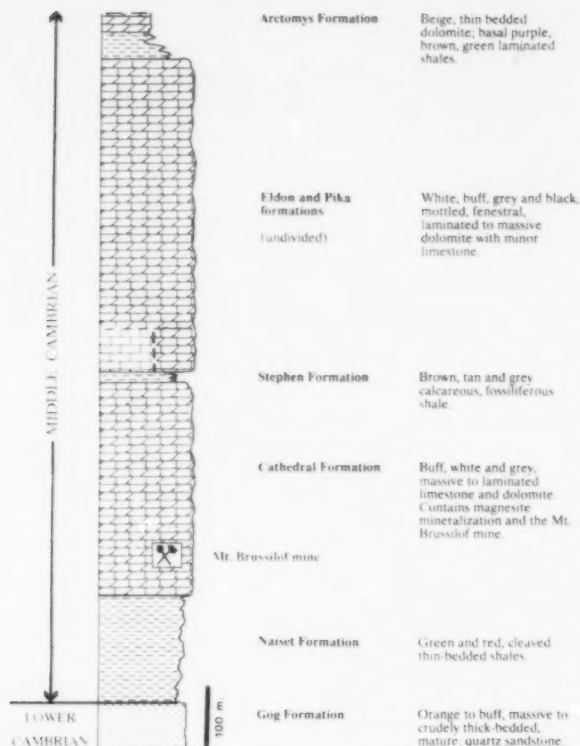


Figure 3. Composite stratigraphic column of the sedimentary sequence east of the Cathedral escarpment, Mount Brussilof mine area. (Simandl and Hancock, 1991).

The Gog Formation is a rusty, grey or buff, medium to coarse-grained, massive to thick-bedded Lower Cambrian sandstone more than 250 metres thick.

The Naiset Formation comprises thinly bedded, brown and green Middle Cambrian shale overlying the Gog Formation. It is 65 to 170 metres thick, characterized by blue-green chlorite spots and by a well-developed cleavage oblique to bedding. Near the Cathedral escarpment this shale may become grey or partially converted to talc and serpentine.

The Cathedral Formation, which hosts the magnesite deposits, is also Middle Cambrian in age. It is about 340 metres thick and consists of buff, white and grey limestones and dolomites. Laminations, ripple marks, intraformational breccias, yoholaminites (McIlreath and Aitken, 1976), algal mats, oolites, pisolites, fenestrae and burrows are well preserved. Pyrite is common either as disseminations or pods and veins.

The Stephen Formation consists of tan to grey, thinly bedded to laminated shale about 16 metres thick, with a cleavage subparallel to bedding. It is of Middle Cambrian age and contains abundant fossil fragments and locally well preserved trilobites and inarticulate brachiopods.

The Eldon and Pika formations cannot be subdivided in the map area. The lowermost beds of the Eldon For-

mation, overlying the Stephen Formation, are black limestones approximately 50 metres thick. This basal unit is very distinctive, containing millimetre to centimetre-scale argillaceous layers that weather to a red, rusty colour; elsewhere these formations can not be readily distinguished from the Cathedral Formation, except by fossil evidence.

The Arctomys Formation, also Middle Cambrian in age, is characterized by green and purple shales and siltstones interbedded with beige, fine-grained dolomites. Mud cracks and halite crystal prints are commonly preserved. The thickness of this formation was not determined, as the base marked the limit of mapping.

All the formations are well exposed over the area, except the recessive Stephen Formation, which was not observed in the southern part of the map area. It is not clear if this lack of exposure is due to lack of outcrops or nondeposition.

STRUCTURE

Rocks west of the Cathedral escarpment are strongly deformed. The deformation is characterized by numerous small-scale folds with subhorizontal fold axes oriented 160° . Minor thrust faults, and a well-developed steeply dipping cleavage striking 160° are other typical features. Along the Cathedral escarpment, cleavage is subvertical, closely spaced and injected by dolomite, calcite and siderite(?) veins.

East of the Cathedral escarpment, cleavage is generally absent in carbonates (Cathedral, Eldon and Pika formations), well developed in the Stephen Formation and strongly developed in the Naiset Formation. The rocks outcropping immediately east of the escarpment strike 170° and dip 20° west.

Farther east the bedding is subhorizontal and characterized by minor, upright, open folds. Several subvertical faults transect this area (Figure 2). These faults have vertical displacements of tens to hundreds of metres. In the northeastern corner of the study area, deformation in the Naiset Formation is similar to that of the Chancellor Formation, due to a thrust fault outcropping farther east.

MAGNESITE DEPOSITS

Sparry carbonate rocks occur within the Cathedral, Eldon and Pika formations (Figure 2). They consist mainly of coarse dolomite and magnesite crystals in varying proportions. Magnesite-rich sparry carbonates are restricted to the Cathedral Formation, where they form lenses, pods and irregular masses.

Barren Cathedral Formation consists mainly of fine-grained, massive or laminated dolomites interbedded with limestones. It contains well-preserved sedimentary and diagenetic features. These fine-grained carbonates are locally brecciated and cemented by coarse white do-

lomite. Parts of the Cathedral Formation are entirely altered to sparry magnesite, forming deposits of economic interest.

Sparry carbonates are separated from limestone by envelopes of light grey, massive dolomite, which may contain needle-shaped quartz crystals. The contacts between sparry carbonate masses and the fine-grained dolomite are sharp and may be concordant or discordant. Magnesitic sparry carbonate is usually white or light grey in colour and buff when weathered. It consists of regularly spaced, alternating white and grey magnesite layers, randomly oriented centimetre-scale white magnesite crystals or a mixture of light grey and white magnesite crystals. Common impurities in magnesite ore are isolated rhombohedral dolomite crystals, calcite veins, pyrite veins, subvertical fractures filled by a mixture of beige ankerite, calcite and chlorite, coarse radiating or single quartz crystals and coarse pyrite pyritohedrons and octahedrons disseminated within sparry magnesite. Chalcocite, fersmite, phlogopite, talc and coarse, white, acicular palygorskite were also observed in the Mount Brussilof mine. Boulangerite, huntite and brucite were reported from laboratory analysis by White (1972).

Where fine-grained dolomite is not entirely converted to magnesite, replacement features such as coarse, white carbonate crystals growing perpendicular to fracture planes, or partings and lenses of fine-grained dolomite enclosed by sparry carbonates, are common. Bipolar growths of zoned magnesite crystals, magnesite pinolite, rosettes and coarse carbonate crystals having lozenge-shaped cross-sections. All these features are interpreted as replacement textures.

Sparry dolomite rock consists mainly of dolomite rhombs. It forms lenses, veins or irregular masses in fine-grained dolomite and is believed to occur at the same stratigraphic horizons and to contain the same impurities as coarse sparry magnesite.

Dolomite veins cut magnesite ore at the mine; however, magnesite veins were never observed to cut sparry dolomite.

CHEMISTRY OF CARBONATE ROCKS

SAMPLE SELECTION AND ANALYSES

A total of 121 carbonate grab samples were collected, each weighing from 2 to 8 kilograms, cleaned of visible surface alteration. The samples are from either the Cathedral or Eldon and Pika formations and are divided into three major categories: sparry carbonates, fine-grained dolomites and limestones. Most of the samples were initially analyzed for major elements using x-ray fluorescence (XRF). However, problems were encountered during the fusion of the highly refractory magnesite-rich samples and inductively coupled plasma atomic emission

spectrometry (ICP-AES) was substituted. All the laboratory procedures, including the method used to determine the loss on ignition (LOI) are described in Appendix I.

INTERPRETATION OF THE GEOCHEMICAL DATA

The results of chemical analyses are reported in Appendix II (Tables I, II and III) and sample sites are located on Figure 2. The previously mentioned change in analytical method is not believed to have a significant effect on the validity of the statistical analyses. Sample 90GS-09/02-58 was analyzed and plotted on Figure 2, but not considered in the statistical analysis. It is a recrystallized carbonate with crystal size varying from a fraction of a millimetre to 2 millimetres across, interbedded with sparry carbonate. This sample does not fit any of the four groups represented on Figures 4, 5, 6 and 7. The results of the statistical analysis are graphically summarized on these figures and in Table IV. Vertical scales of the figures are logarithmic to permit the representation of elements with an extreme range of variations on the same diagram. The use of the median and quartiles is preferred since the frequency distributions for the elements analyzed are not normal. However, the average and standard deviation have been calculated.

The magnesium content of the carbonate rocks varies continuously from dolomite to magnesite and there is also a substantial spread between dolomite and calcite (Figure 8). The compositions of stoichiometric calcite, dolomite and magnesite are given for reference. Fine-grained carbonates are limy or dolomitic in composition. Coarse and sparry carbonates have generally higher magnesia content than fine-grained carbonates. Sparry carbonate occurrences observed in the field but not analyzed are represented by large quarter-filled circles (Figure 2). Samples substantially exceeding 21.7 per cent MgO (the composition of stoichiometric dolomite) must contain at least some magnesite, unless other magnesium-rich minerals such as huntite, hydromagnesite or brucite are present. Magnesite-bearing rocks with an MgO content slightly higher than 70 per cent after calcination (equivalent to 36.5% before calcination, as reported in Appendix II) are not usable for high-quality refractories without upgrading. However, they may have applications in other areas such as production of magnesium metal and possibly in environmental rehabilitation. The known locations of these rocks are represented by fully filled circles (Figure 2). The rock used for manufacturing high-performance magnesia-based refractories without upgrading should approach the composition of the samples from the mine site (Figure 7).

In general, the samples from the Eldon Formation have a lower magnesia content than the samples from the Cathedral Formation. All the samples assaying over 36.5 per cent MgO (70% MgO after calcination) are from the Cathedral Formation (Figure 2). All the sparry carbon-

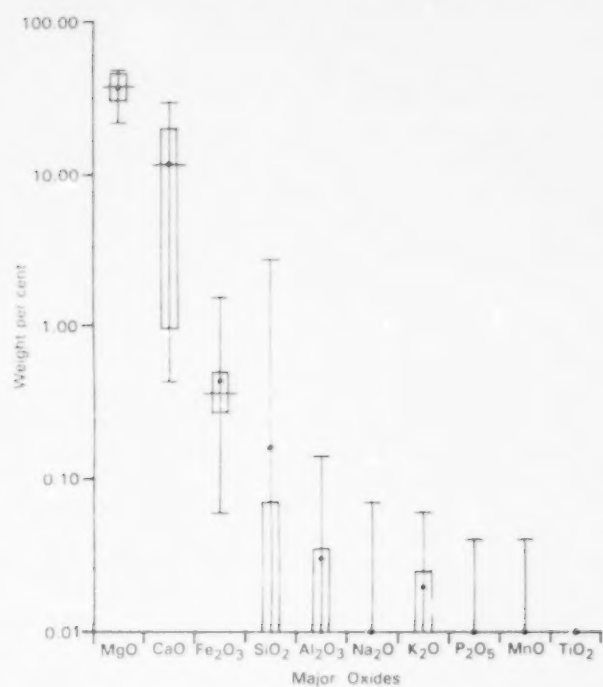


Figure 4. Major oxide content of sparry carbonates, Mount Brussilof area. Total iron expressed as Fe_2O_3 .

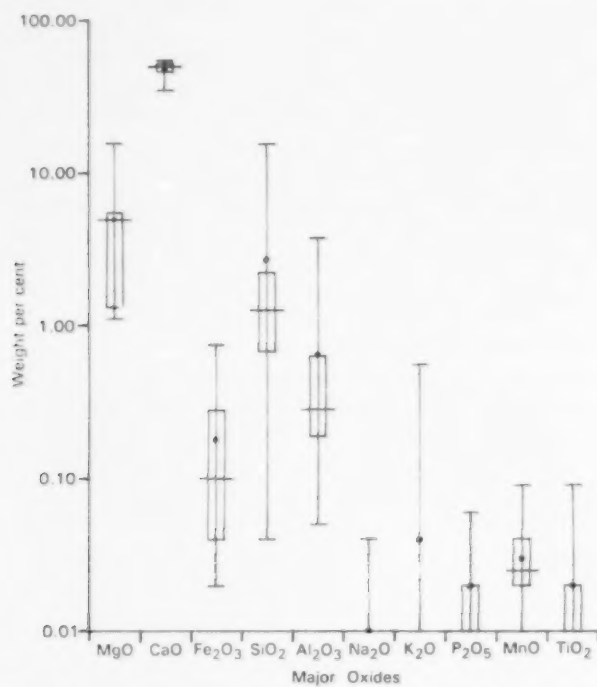


Figure 5. Major oxide content of limestones, Mount Brussilof area. Total iron expressed as Fe_2O_3 .

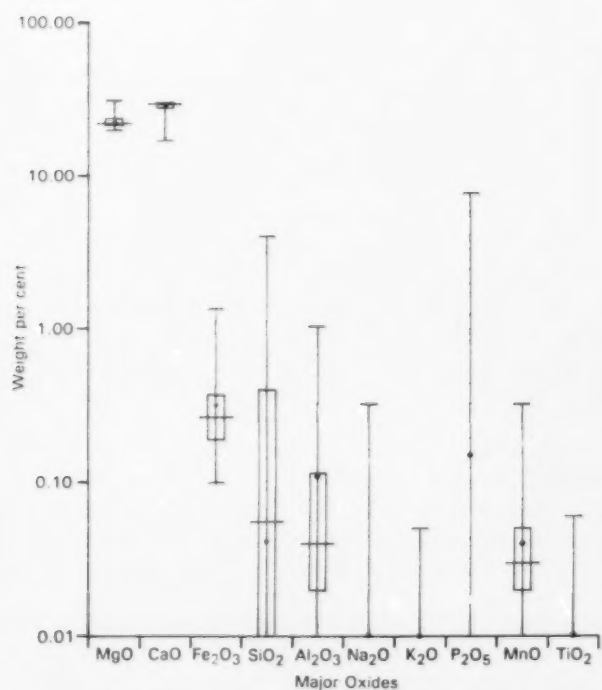


Figure 6. Major oxide content of the fine-grained dolomites, Mount Brussilof area. Total iron expressed as Fe_2O_3 .

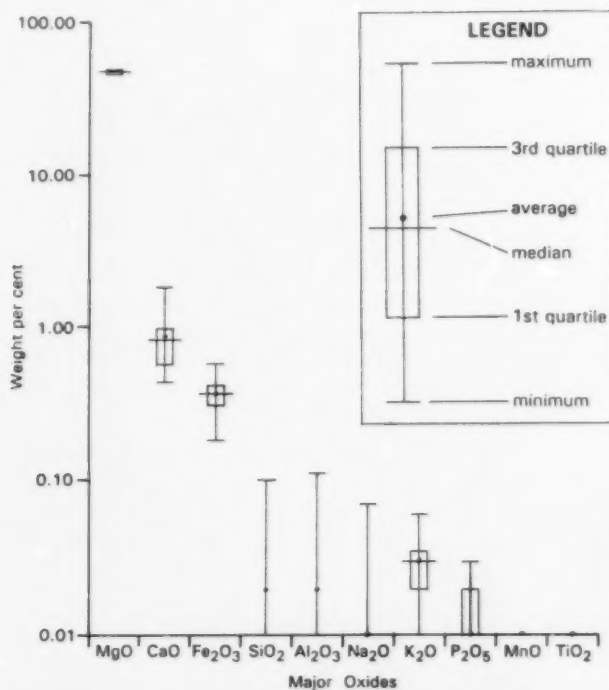


Figure 7. Major oxide content of sparry carbonate rocks, Mount Brussilof mine site. Total iron expressed as Fe_2O_3 .

ates of the area are characterized by a very low Fe_2O_3 , MnO , SiO_2 , Al_2O_3 , TiO_2 , K_2O and Na_2O contents (Table III and IV) indicating that these elements will probably not impair the use of magnesite. Iron content decreases with increasing magnesia content (Figures 5, 6 and 7).

Sparry carbonate is widespread throughout the Cathedral Formation, and also occurs within the Eldon and Pika formations. Chemical analyses indicate that all known magnesia-rich sparry carbonate occurrences are confined to the Cathedral Formation. About 1 kilometre north and east of the mine the favorable horizon of the Cathedral Formation is covered by barren Eldon Formation. This mineralization may extend beneath the barren Eldon Formation as suggested by sparry carbonate showings along the Assiniboine Creek valley. The belt may extend south of the Miller Pass showings (Figure 2). All

known sparry carbonate outcrops and the samples with magnesia content exceeding 70 per cent after calcination are high-lighted on Figure 2. The raw data contained in Appendix II, in conjunction with the sample locations, permit re-evaluation if market conditions change, if new technology is developed or if additional parameters such as MgO/CaO ratio or SiO_2/CaO ratios are required by the reader.

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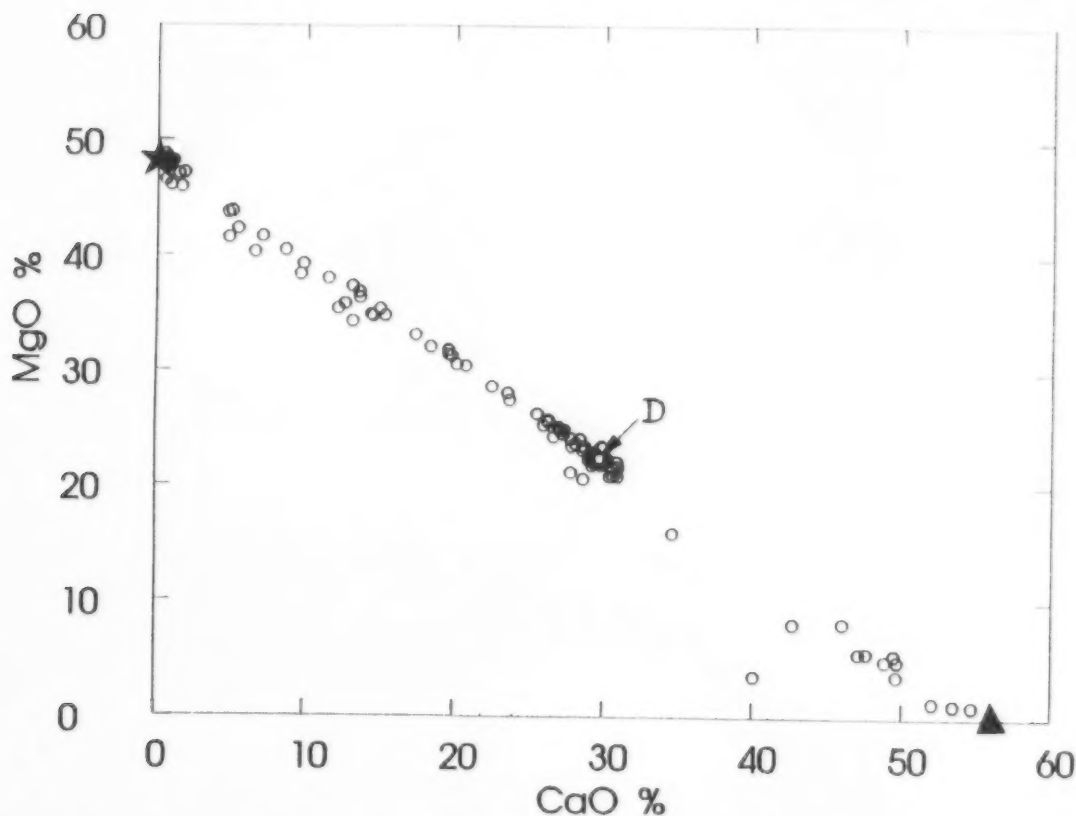


Figure 8. Induced negative correlation between MgO and CaO in carbonate rocks, Mount Brussilof area. The distribution of the data suggests a continuum in composition. Star - stoichiometric magnesite, Small square labelled D - stoichiometric dolomite, Triangle - stoichiometric calcite.

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APPENDIX I

ANALYTICAL PROCEDURES

SAMPLE PREPARATION

All of the rock samples were jaw crushed to 5-millimetre sized fragments and reduced to a 500 gram sub-sample by passing the crushed rock several times through a Jones splitter. The subsample was split into one portion which was stored for archiving and a second 250 to 300-gram portion which was ring pulverized in a tungsten-carbide mill to finer than 100 mesh. All rock sample preparation was performed in the Analytical Sciences Laboratory, British Columbia Geological Survey Branch.

ANALYSIS OF SAMPLES FOR MAJOR OXIDES BY X-RAY FLUORESCENCE

Major oxides, SiO_2 , Al_2O_3 , Fe_2O_3 , MgO , CaO , Na_2O , K_2O , TiO_2 , MnO and P_2O_5 were determined by x-ray fluorescence in the Analytical Sciences Laboratory using a Philips PW1404 automated wavelength dispersive spectrometer system. A 2-gram aliquot of the sample pulp was mixed with 10 grams of a flux comprising 80 per cent lithium tetraborate and 20 per cent lithium metaborate and fused in a platinum-gold crucible to prepare a glass disc. A primary x-ray beam, directed onto the disc, excites elements to emit secondary x-ray fluorescence. The intensity of the fluorescence was measured by gas-filled or

scintillation counters. Calibration of the x-ray fluorescence spectrometer was performed using rock and mineral standard reference materials. Analytical precision was better than 2 per cent relative standard deviation for all of the major oxides.

ANALYSIS OF SAMPLES FOR MAJOR OXIDES BY INDUCTIVELY COUPLED PLASMA ATOMIC EMISSION SPECTROSCOPY (ICP-AES)

Major oxides, SiO_2 , Al_2O_3 , Fe_2O_3 , MgO , CaO , Na_2O , K_2O , TiO_2 , MnO and P_2O_5 were determined at Chemex Laboratories, Vancouver by inductively coupled plasma atomic emission spectroscopy. A 0.1-gram sample was fused in a furnace at 1050°C with 0.7 gram of lithium metaborate flux. The fused material was cooled and dissolved in 4 per cent nitric acid. The elements were determined by ICP-AES using a Jarrell Ash ICP spectrometer. The results are corrected for spectral interferences. The detection limit for all of the major oxides is 0.01 per cent.

LOSS ON IGNITION

A 3.0-gram aliquot of the sample was weighed into a tared crucible, heated at 1050°C for 3 to 4 hours and the weight loss reported as loss on ignition (LOI). Loss on ignition was measured by the Analytical Sciences Laboratory.

APPENDIX II

CHEMICAL ANALYSES OF CARBONATES, MOUNT BRUSSILOF AREA

TABLE I
CHEMICAL ANALYSES OF LIMESTONES

SAMPLE	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	LOI	TOTAL
26	0.57	0.00	0.19	0.24	0.09	8.07	46.04	0.00	0.00	0.01	44.69	99.90
66	0.68	0.01	0.19	0.04	0.01	4.91	49.69	0.00	0.01	0.01	44.15	99.70
66DUP	0.71	0.01	0.22	0.04	0.02	4.89	48.86	0.00	0.00	0.01	44.20	98.96
100	1.66	0.01	0.49	0.06	0.03	1.13	53.46	0.00	0.00	0.01	43.01	99.86
101	1.55	0.01	0.34	0.07	0.06	3.60	49.63	0.00	0.00	0.01	43.62	98.89
104	0.54	0.00	0.05	0.02	0.01	1.02	54.70	0.00	0.00	0.00	43.57	99.91
106	0.04	0.00	0.05	0.11	0.05	5.41	49.48	0.00	0.00	0.01	44.58	99.73
162	2.07	0.02	0.64	0.14	0.02	1.33	52.02	0.00	0.00	0.02	42.54	98.80
165	1.02	0.01	0.23	0.09	0.03	5.54	47.63	0.00	0.00	0.01	44.17	98.73
199	15.41	0.09	3.72	0.75	0.03	3.54	40.07	0.04	0.56	0.06	35.66	99.93
C-3	4.26	0.01	0.38	0.32	0.01	15.85	34.59	0.00	0.00	0.05	44.41	99.88
C-7	2.19	0.02	0.71	0.28	0.02	5.51	47.10	0.00	0.00	0.02	43.34	99.19
C1	4.54	0.04	1.49	0.38	0.02	8.03	42.71	0.00	0.04	0.02	42.28	99.55
L-2	0.01	0.01	0.01	0.63	0.01	35.39	12.15	0.01	0.01	0.01	50.20	98.44
P-11A	0.80	0.01	0.18	0.04	0.04	1.13	53.44	0.00	0.00	0.02	43.52	99.18

TABLE II
CHEMICAL ANALYSES OF DOLOMITES

SAMPLE	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	LOI	TOTAL
14	0.07	0.00	0.04	0.28	0.01	24.78	27.11	0.00	0.00	0.01	47.15	99.45
35	0.02	0.00	0.04	0.18	0.03	22.04	29.91	0.00	0.00	0.01	47.45	99.88
58	0.01	0.01	0.01	0.26	0.01	47.60	0.90	0.01	0.02	0.02	51.31	100.16
59	0.63	0.00	0.07	0.13	0.03	21.56	30.98	0.00	0.00	0.01	46.72	100.13
60	0.42	0.00	0.11	0.11	0.03	22.17	29.59	0.00	0.00	0.00	47.02	99.45
61	0.02	0.00	0.03	0.15	0.01	31.31	19.54	0.00	0.00	0.01	48.34	99.91
68	0.50	0.01	0.15	0.10	0.02	22.31	30.01	0.00	0.00	0.01	46.83	99.94
70	0.82	0.02	0.46	0.94	0.20	20.74	30.46	0.03	0.00	0.01	46.37	100.05
73	0.38	0.01	0.17	0.36	0.07	21.95	29.39	0.00	0.00	0.01	47.01	99.35
78	0.05	0.00	0.06	0.33	0.12	22.08	30.02	0.00	0.00	0.00	47.24	99.90
80	0.00	0.00	0.00	0.14	0.02	22.06	29.50	0.00	0.00	0.01	47.39	99.12
84	0.03	0.00	0.01	0.28	0.01	28.03	23.59	0.00	0.00	0.00	47.95	99.90
85	0.00	0.00	0.02	0.27	0.04	22.39	29.62	0.00	0.00	0.00	47.39	99.73
102	0.12	0.00	0.09	0.29	0.04	21.99	29.64	0.00	0.00	0.01	47.32	99.50
105	1.00	0.01	0.15	0.40	0.05	20.83	30.68	0.00	0.00	0.01	46.69	99.82
107	0.00	0.00	0.02	0.17	0.05	22.13	29.90	0.00	0.00	0.01	47.49	99.77
127	0.06	0.00	0.05	0.38	0.04	22.71	29.36	0.00	0.00	0.01	47.39	100.00
128	0.03	0.00	0.04	0.48	0.01	26.22	25.54	0.00	0.00	0.00	47.81	100.13
130	1.21	0.00	0.01	0.16	0.01	23.62	28.18	0.00	0.00	0.01	46.79	99.99
132	3.74	0.06	1.03	0.51	0.03	21.11	27.86	0.32	0.00	0.02	44.54	99.22
133	0.71	0.00	0.05	0.24	0.02	24.19	26.69	0.00	0.00	0.00	47.21	99.11
135	0.03	0.00	0.02	0.26	0.05	21.58	30.67	0.00	0.00	0.01	47.32	99.94
141	0.02	0.00	0.01	0.22	0.03	22.32	29.79	0.00	0.00	0.01	47.48	99.88
146	0.00	0.00	0.01	0.53	0.07	22.13	29.94	0.00	0.00	0.00	47.30	99.98
160	0.00	0.01	0.01	0.25	0.03	22.19	30.04	0.00	0.00	0.01	47.40	99.94
170	0.01	0.00	0.02	0.15	0.03	22.66	29.63	0.00	0.00	0.00	47.42	99.92
171	0.00	0.00	0.00	0.15	0.01	23.93	28.48	0.00	0.00	0.00	47.33	99.96
172	0.00	0.00	0.03	0.40	0.01	24.79	27.40	0.00	0.00	0.00	47.24	99.87
173	0.21	0.00	0.03	0.21	0.04	22.66	29.56	0.00	0.00	0.00	47.18	99.89
175	0.36	0.00	0.03	0.24	0.08	21.94	30.14	0.00	0.00	0.00	47.18	99.97
181	0.00	0.00	0.02	0.41	0.08	22.02	30.93	0.00	0.00	0.00	46.62	100.08
195	0.03	0.00	0.03	0.34	0.05	22.24	30.03	0.00	0.00	0.01	47.27	100.00
202	0.18	0.01	0.12	0.82	0.13	21.57	30.65	0.00	0.00	0.00	46.56	100.04
206	0.02	0.00	0.01	1.36	0.32	20.74	30.95	0.00	0.00	0.00	46.83	100.23
215	0.01	0.00	0.01	0.29	0.04	23.01	28.67	0.00	0.00	0.00	47.30	99.33
215DUP	0.06	0.00	0.03	0.30	0.03	22.88	29.43	0.00	0.00	0.00	47.20	99.93
226	4.07	0.03	0.80	0.28	0.05	20.56	28.67	0.00	0.05	0.03	44.84	99.38
232	0.00	0.00	0.04	0.20	0.01	24.40	27.36	0.00	0.00	0.00	47.38	99.39
236	2.51	0.01	0.21	0.24	0.02	21.72	29.28	0.00	0.00	0.01	45.90	99.90
240	0.00	0.00	0.06	0.22	0.02	23.41	28.76	0.00	0.00	0.00	47.23	99.70
241	0.18	0.01	0.15	0.22	0.02	22.32	30.26	0.00	0.00	0.01	46.99	100.16
245	1.07	0.02	0.70	0.32	0.02	23.40	27.92	0.00	0.00	0.01	46.42	99.88
246	0.00	0.00	0.03	0.29	0.02	24.06	27.86	0.00	0.00	0.00	47.72	99.98
254	0.00	0.00	0.01	0.18	0.02	22.77	29.08	0.00	0.00	0.00	47.42	99.48
270	0.07	0.00	0.03	0.21	0.02	25.18	26.03	0.00	0.00	0.07	47.45	99.06
285	0.23	0.00	0.04	0.18	0.02	22.43	29.27	0.00	0.00	0.01	47.27	99.45
297	0.03	0.00	0.02	0.27	0.02	30.54	20.12	0.00	0.00	0.00	46.92	99.92
C5	0.30	0.01	0.19	0.52	0.06	22.05	30.20	0.00	0.00	0.01	46.94	100.28
C6	0.06	0.02	0.07	0.42	0.05	21.88	30.07	0.03	0.00	0.09	47.12	99.81
C6B	0.05	0.00	0.05	0.49	0.02	24.52	27.26	0.00	0.00	0.00	47.33	99.72
C7B	1.24	0.00	0.19	0.21	0.03	22.16	29.06	0.05	0.00	0.01	46.74	99.69
L1	0.05	0.01	0.04	0.28	0.04	22.27	29.20	0.00	0.01	0.00	47.40	99.30
P-11B	0.82	0.00	0.07	0.24	0.03	21.75	29.87	0.00	0.00	0.01	47.13	99.92
P45B	0.19	0.00	0.17	0.12	0.01	33.12	17.34	0.00	0.00	7.70	40.75	99.40

TABLE III
CHEMICAL ANALYSES OF SPARRY CARBONATES

SAMPLE	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	LOI	TOTAL
108	0.01	0.01	0.01	0.33	0.01	35.80	12.58	0.01	0.04	0.01	49.45	98.26
129	0.02	0.00	0.01	0.31	0.01	25.07	26.70	0.00	0.00	0.00	47.51	99.63
131	0.07	0.00	0.02	0.30	0.01	28.57	22.52	0.00	0.00	0.01	48.08	99.58
182	0.01	0.01	0.01	0.34	0.01	38.00	11.50	0.01	0.01	0.01	49.85	99.76
183	0.07	0.00	0.04	0.14	0.01	23.22	29.98	0.00	0.00	0.01	46.38	99.85
191	0.56	0.00	0.07	0.13	0.01	31.38	19.55	0.00	0.00	0.00	48.23	99.93
194	0.12	0.01	0.07	0.24	0.01	31.29	19.79	0.00	0.00	0.02	48.21	99.76
200	0.03	0.00	0.03	0.36	0.01	27.40	23.73	0.00	0.00	0.00	47.82	99.38
201	0.01	0.01	0.01	0.68	0.01	35.36	14.93	0.01	0.01	0.01	48.07	99.11
204	0.01	0.01	0.01	0.99	0.01	43.80	5.04	0.01	0.01	0.01	50.93	100.83
211	0.00	0.00	0.01	0.18	0.04	22.45	29.21	0.00	0.00	0.00	47.43	99.32
214	0.12	0.00	0.03	0.17	0.03	25.52	26.30	0.03	0.00	0.00	47.55	99.75
256	0.12	0.01	0.10	0.37	0.02	30.42	20.74	0.00	0.00	0.00	48.51	100.29
258	0.29	0.01	0.10	0.34	0.01	32.08	18.34	0.00	0.00	0.00	48.71	99.88
260	0.01	0.00	0.03	0.43	0.03	26.13	25.61	0.00	0.00	0.00	47.56	99.80
271	0.01	0.01	0.01	0.41	0.01	41.63	7.10	0.01	0.01	0.01	49.66	98.87
274	0.01	0.01	0.01	0.28	0.01	37.31	13.07	0.01	0.01	0.01	48.08	98.81
275	0.00	0.00	0.01	0.73	0.01	25.01	27.03	0.00	0.00	0.01	46.38	99.18
276	0.01	0.01	0.02	0.63	0.01	39.24	9.85	0.03	0.02	0.01	50.06	99.89
284	0.08	0.01	0.04	0.22	0.01	25.66	26.34	0.00	0.00	0.02	47.52	99.90
294	0.01	0.01	0.01	0.47	0.01	40.43	8.64	0.01	0.01	0.01	50.70	100.31
030	0.45	0.01	0.01	0.92	0.01	43.67	4.78	0.01	0.02	0.04	49.97	99.89
034	0.01	0.01	0.01	0.54	0.01	38.33	9.67	0.01	0.03	0.01	50.13	98.76
047	0.01	0.01	0.01	0.29	0.01	36.35	13.57	0.01	0.02	0.02	47.38	97.68
048	2.73	0.01	0.07	1.07	0.01	40.26	6.58	0.01	0.01	0.02	48.25	99.02
057	2.43	0.01	0.14	0.26	0.01	34.26	13.12	0.08	0.04	0.01	47.32	97.66
063DUP	0.01	0.01	0.01	0.25	0.01	36.83	13.53	0.01	0.02	0.01	50.22	100.91
067	0.83	0.00	0.03	1.52	0.01	23.39	28.66	0.00	0.00	0.01	44.67	99.12
067A	0.00	0.00	0.02	0.06	0.01	23.36	29.90	0.00	0.00	0.00	46.84	100.19
071	0.01	0.01	0.14	0.42	0.01	41.48	4.84	0.01	0.04	0.01	51.04	98.01
077	0.01	0.01	0.01	0.18	0.01	34.78	15.27	0.01	0.02	0.01	47.26	97.57
090	0.19	0.00	0.05	0.28	0.04	22.17	29.80	0.00	0.00	0.01	47.32	99.86
091	0.01	0.01	0.07	0.42	0.01	42.28	5.45	0.04	0.02	0.02	50.35	98.68
092	0.01	0.01	0.01	0.82	0.01	34.87	14.33	0.01	0.01	0.01	48.83	98.92
092DUP	0.01	0.01	0.01	0.82	0.01	34.75	14.47	0.01	0.02	0.01	48.66	98.78
P-11C	0.01	0.01	0.01	0.42	0.01	47.89	0.87	0.01	0.05	0.01	52.02	101.31
P-13	0.01	0.01	0.01	0.40	0.01	48.24	0.58	0.01	0.02	0.01	51.95	101.25
P-28	0.01	0.01	0.01	0.29	0.01	47.82	0.55	0.01	0.05	0.01	51.01	99.78
P-34A	0.01	0.01	0.01	0.35	0.01	48.00	0.82	0.01	0.03	0.02	51.96	101.23
P-34B	0.01	0.01	0.01	0.36	0.01	48.33	0.57	0.01	0.02	0.01	51.85	101.19
P-37	0.01	0.01	0.01	0.20	0.01	45.99	0.90	0.01	0.03	0.01	52.98	100.16
P-37DUP	0.01	0.01	0.01	0.18	0.01	46.04	0.91	0.01	0.03	0.01	52.12	99.34
P-41	0.01	0.01	0.01	0.32	0.01	48.71	0.50	0.01	0.03	0.01	51.73	101.35
P-43B	0.01	0.01	0.01	0.40	0.01	48.09	0.80	0.01	0.04	0.02	52.21	101.41
P-52A	0.01	0.01	0.01	0.36	0.01	48.34	0.43	0.01	0.02	0.02	52.31	101.53
P-52B	0.01	0.01	0.12	0.31	0.01	48.35	0.57	0.01	0.06	0.02	52.01	101.48
P01	0.01	0.01	0.04	0.46	0.01	45.86	1.63	0.07	0.02	0.01	51.53	99.65
P10A	0.10	0.01	0.01	0.38	0.01	47.00	1.41	0.01	0.02	0.03	51.44	100.42
P01DUP	0.01	0.01	0.01	0.57	0.01	47.10	1.82	0.01	0.02	0.01	51.50	101.07
P44A	0.01	0.01	0.01	0.37	0.01	48.12	1.02	0.01	0.01	0.01	51.86	101.44
P53	0.01	0.01	0.01	0.51	0.01	47.74	0.85	0.01	0.01	0.02	51.88	101.06
P06	0.01	0.01	0.01	0.24	0.01	46.47	0.56	0.01	0.03	0.01	52.19	99.55

TABLE IV
STANDARD DEVIATIONS AND AVERAGES FOR SELECTED ROCK TYPES

Rock type	MgO	CaO	Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	Na ₂ O	K ₂ O	P ₂ O ₅	MnO	TiO ₂
LIMESTONE										
Average	5.00	47.82	0.18	2.57	0.63	0.00	0.04	0.02	0.03	0.02
Std. Dev. (n-1)	3.93	5.57	0.20	3.93	0.96	0.01	0.15	0.02	0.02	0.02
DOLOMITE										
Average	23.21	28.52	0.32	0.41	0.11	0.01	0.00	0.15	0.04	0.00
Std. Dev. (n-1)	2.56	2.78	0.22	0.84	0.20	0.04	0.01	1.06	0.05	0.01
SPARRY CARBONATE										
Average	37.66	11.87	0.43	0.16	0.03	0.01	0.02	0.01	0.01	0.01
Std. Dev. (n-1)	8.82	10.26	0.27	0.51	0.03	0.01	0.02	0.01	0.01	0.00
SPARRY CARBONATE (PIT)										
Average	47.53	0.86	0.36	0.02	0.02	0.01	0.03	0.01	0.01	0.01
Std. Dev. (n-1)	0.93	0.41	0.10	0.02	0.03	0.01	0.01	0.01	0.00	0.00

**MAPS
NOT
FILMED**

**CARTES
OMISES**